FUNDAMENTAL STUDY FOR RESISTANCE OF COASTAL DIKE WITH CONCRETE PANELS AGAINST COMPOUND DISASTER OF EARTHQUAKE AND TSUNAMI

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ABSTRACT

Compound disaster due to earthquake and tsunami may cause collapse of coastal dike and then serious human damages like 2011 Great East Japan Earthquake. The present study aims to clarify the fundamental resistance of reinforced coastal dike with concrete panels against earthquake and tsunami overflow. For this, we used a new experimental channel for the compound disaster due to earthquake and tsunami. The experimental results indicated that the gaps between panels on the back slope of the dike were generated due to the earthquake. This part became the trigger for dike breach due to tsunami overflow, showing that the compound disaster may depress the resistance of armored dike against tsunami overflow.

Keywords: compound disaster, tsunami, earthquake, coastal dike, laboratory experiment

1. INTRODUCTION

In recent years, various types of disasters have occurred in Japan like Osaka earthquake, the western heavy rain, typhoon Jebi and Hokkaido Iburi eastern earthquake in 2018. There are concerns for compound disaster in which multiple types of disasters occur simultaneously. The types of compound disasters include "earthquake and tsunami", "earthquake and landslide", "earthquake and volcanic eruption", "storm surge and flood" and "earthquake and flood".

Compound disaster due to earthquake and tsunami may cause collapse of coastal dike and then serious human damages like 2011 Great East Japan Earthquake. In Miyako City, Iwate Prefecture, Japan, the coastal dike in the area settled 100cm by the earthquake and were broken down by tsunami after it. In addition, around 60% of the coastal dike in Sendai-southern coast were collapsed by tsunami overflow. Since the Great East Japan Earthquake, the design force of coastal levees is assumed to be high frequency tsunami (L1) and the largest tsunami (L2). Especially, coastal dike needs to have a resilience which can prolong the duration for dike breach due to tsunami overflow to keep the evacuation time. However, the compound disaster of earthquakes and tsunamis is not considered for design of coastal dike.
The present study aims to clarify the fundamental resistance of reinforced coastal dike with concrete panels against earthquake and tsunami overflow. For this, we used a new experimental channel for the compound disaster due to earthquake and tsunami (Nihei and Kurakami, 2018). Using the channel, we examined the resistance of the coastal dike with concrete panels against earthquake and tsunami compound disaster.

2. METHOD

2.1 Channel for the compound disaster

Figure 1 shows the schematic view and photograph of the channel, which was used to simulate a compound disaster due to earthquake and tsunami. The channel is composed of three parts: a channel for earthquakes, a connection, and a channel for flood and tsunami. The total length, width, and height of the channel is 33 m, 0.60 m, and 1.0 m, respectively. In the earthquake test, the connection part is removed and the earthquake generator is set. This system can generate sine waves with a maximum acceleration of more than 1000 gal and period of 0.4 – 0.5 s. In this channel, one-dimensional oscillating motion along the channel was generated. In the tsunami experiment, the three channels are connected. Tsunami generator and pump located in the channel for tsunami are used to generate a tsunami overflow.

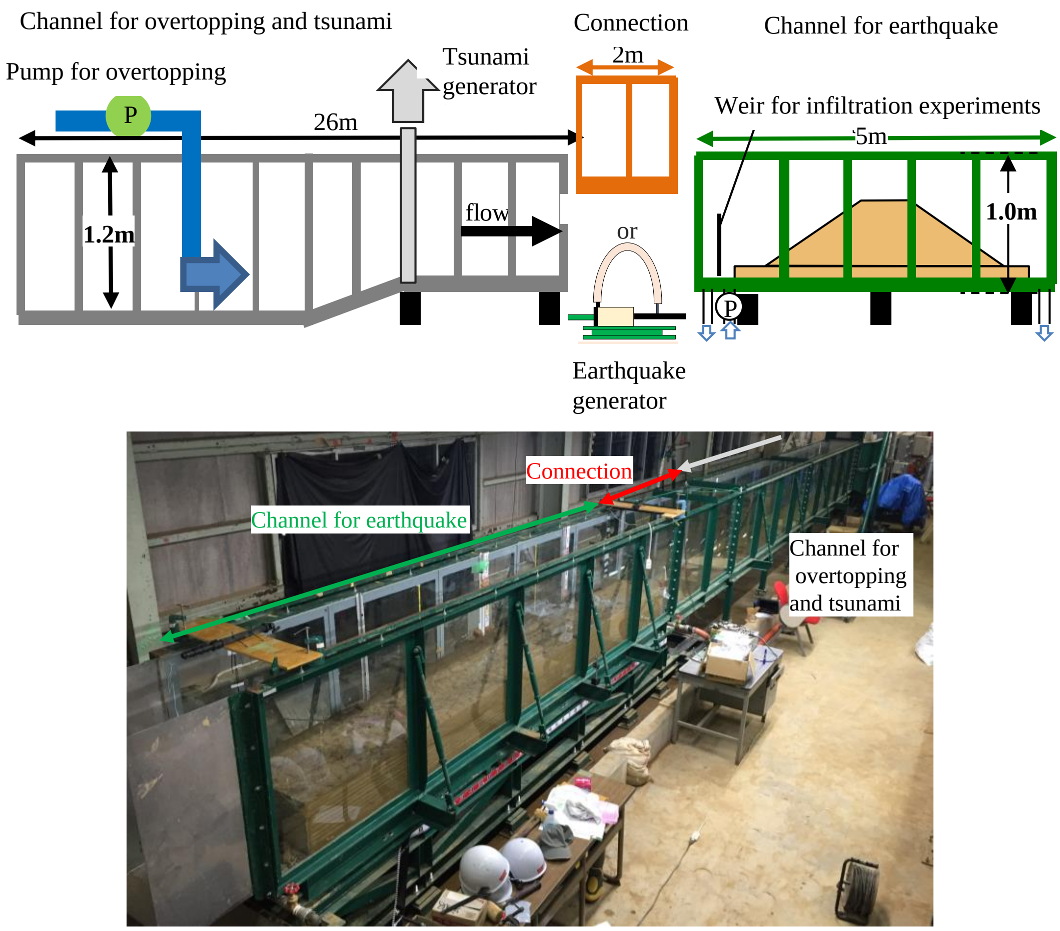

Fig. 1 Schematic views of a new facility for model-levee tests for compound disasters of earthquake, flood, and tsunami (Upper: schematic view, lower: photograph).

2.2 Experimental conditions for the compound disaster

In the earthquake-tsunami compound disaster, we used the model coastal dike as shown in **Fig. 2**. The model scale was 1/10 of a prototype levee in Sendai south coast, Japan. The height and foundation thickness were 40 cm and 30 cm, respectively. The front and back slopes were set to 1:2. The model dike was composed of concrete panels, filter layers, non-woven sheet and dike material. The concrete panels were installed on the top and back- and front-slopes of the dike. The filter layers of crash stones (2.5 to 5.0 mm) were laid under the concrete panels on the back- and front-slopes. Hokota sand with the median diameter D_{50} = 0.18mm and fraction of fine sand F_c = 12.3 % was used as the dike material. We set the sand with the compaction degree Dc = 90 % and an optimal water content.

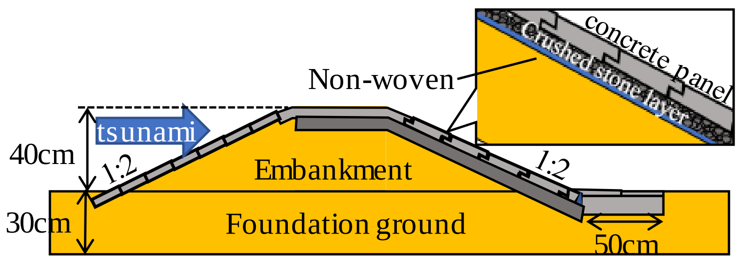

Fig. 2 Model dike with concrete panels used in the experiment.

We set two cases with and without the earthquake experiment; In Case 1, the compound disaster due to earthquake and tsunami was given in the model dike. In the earthquake experiment, 30 sine waves with the acceleration of 400 and 800 gals were given. After the earthquake experiment, the tsunami experiment was conducted. The difference of water level between offshore and shoreside of the tsunami generator, Δh, was set to 0.80 m. The discharge of the pump, Q, was to 0.065 m^3/s. In Case 2, we conducted only tsunami experiment with the same Δh and Q as Case 1. The comparison of the results between Case 1 and Case2 show the effect of earthquake on the resistance of the coastal dike against tsunami overflow.

3. RESULTS AND DISCUSSION

The results for the earthquake experiment in Case1 are shown in **Fig. 3**. The shapes of the model dike at 20th and 30th waves are depicted in the figure. At the 10th wave omitted in the figure, the deformation of the filter layer was already seen, and a step of the concrete panels between the crest end and the back-slope began to occur. At the 20th wave, the deformation of the filter layer that occurred at the 10th wave increased, and the panel on the crest began to tilt. In addition, gaps and irregularities between the panels occurred, the slope protruded, and a large crack occurred near the front shoulder. At the 30th wave, the deformation of the filter layer progressed further, and the gap between the panels occurred and expanded not only on the back-slope but also on the front-slope.

Figure 4 indicated the time series of the residual rates of cross-sectional area and crest height of the model dike both in Case1 and Case 2. It is noted that the residual rates in Case 2 were smaller than those in Case 1. In Case 1, erosion of the dike due to tsunami overflow begun to occur near the gaps and steps of the concrete panels which were deformed due to the earthquake experiment. This fact suggests that the compound disaster may depress the resistance of armored dike against tsunami overflow.

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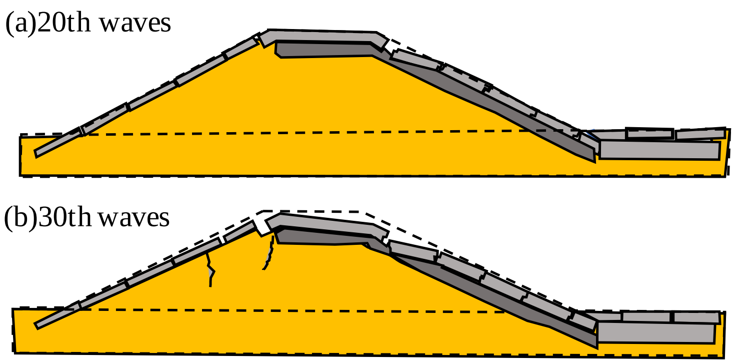

Fig. 3 Deformation pattern of the model dike in the earthquake experiment (Case 1).

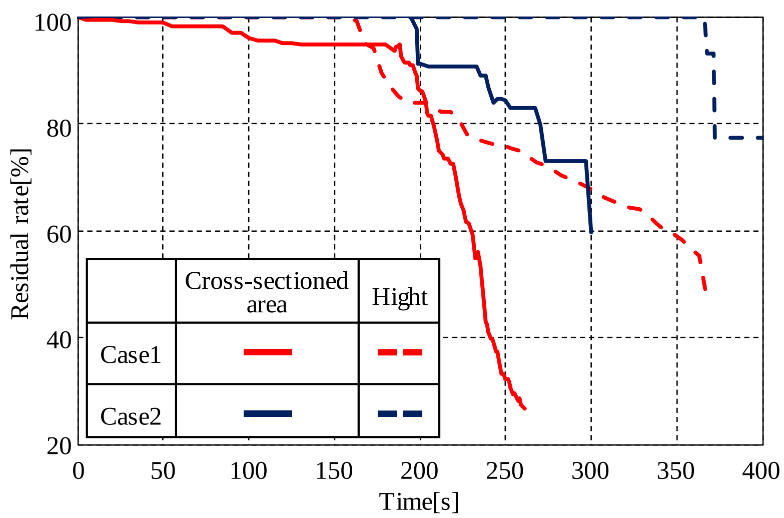

Fig. 4 Time series of the residual rate of the cross-sectional and crest height of the model dike.